

THE HYDROLOGIC CYCLE DISTRIBUTED ACTIVE ARCHIVE CENTER

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ABSTRACT

The Marshall Space Flight Center Distributed Active Archive Center in Huntsville, Alabama supports the acquisition, production, archival and dissemination of data relevant to the study of the global hydrologic cycle. This paper describes the Hydrologic Cycle DAAC, surveys its principle data holdings, addresses future growth, and gives information for accessing the data sets.

1. INTRODUCTION

On October 27, 1994 NASA Administrator Dan Goldin christened a new center dedicated to understanding the global hydrologic cycle. The Global Hydrology and Climate Center (GHCC) brings together under one roof, Earth scientists from Marshall Space Flight Center's (MSFC) Earth System Science Division, and from the Atmospheric Science Department of the University of Alabama in Huntsville plus scientists of the Universities Space Research Association. These Earth scientists are joined by computer scientists, engineers and students forming a center of excellence dedicated to the further understanding of the role of water on our planet.

A major component of the GHCC, providing data production, archive, access and distribution, is the MSFC Hydrologic Cycle DAAC. The DAAC is home to an archive, currently in excess of 450 GBytes, of hydrologic data.

The existing hydrologic data are a combination of remotely sensed and in-situ observations with the majority of current holdings derived from instruments aboard polar orbiting satellites such as the Special Sensor Microwave Imager (SSM/I) on the Defense Meteorological

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Satellite Program (DMSP) platforms and the Microwave Sounding Unit aboard a series of NOAA satellites. Geophysical parameters such as precipitation, water vapor, cloud water content, land classification, and land surface temperature are derived from these satellite data.

Aircraft flight data from the Tropical Ocean Global Atmosphere Coupled Ocean Atmosphere Response Experiment (TOGA/COARE) and stream flow data sets from the USGS Hydro-Climate Data Network represent regional hydrologic data holdings. Other in-situ data range from numerous surface and shipboard rain gauge data sets to radar derived rainfall for unusual natural occurrences such as the Midwest Floods of 1993.

All of these hydrologic data are available to Earth scientists, educators and the general public as part of the EOSDIS program. The data can be ordered through an on-line system, which provides the capability to preview reduced resolution images of the data products, or by contacting the MSFC User Services office by e-mail or phone. Several distribution media are available including electronic transfer via anonymous ftp. The goal is to support hydrologic and other Earth Science research by making this data available to every scientist.

2. DAAC COMPUTATIONAL AND ARCHIVE RESOURCES

The primary computing resources of the DAAC are two Silicon Graphics Challenge class computers used for data ingest, product generation and IMS functions. The combined hard disk capability of these two machines is 50 GBytes. Another 15 Silicon Graphics Indy class workstations are available for software development, operations support and User Services functions. Data orders and system backups are supported by three 8mm tape stacker units, each with a ten tape capacity. Four additional 8mm tape drives, two 4mm drives and two 9-track devices provide a variety of magnetic tape media options. A RAID system provides another 20 GBytes of hard disk capacity.

There is also a CD mastering facility that allows production of small quantities of CD-ROM platters. Mass orders on CD-ROM are filled by high volume production provided by Disk Manufacturing Incorporated, a local Huntsville company.

The mass storage system is a Cygnets WORM Optical Storage System Jukebox with a capacity of 1.25 TBytes. The jukebox holds 135 12" optical platters with a capacity of 4.5 GBytes per side. The write speed is 200 KBytes/sec and the read speed is 500KBytes/second. This

system has been in place since September of 1993. Since its installation there has been a steady migration of data from magnetic media to the optical disks. In addition the data ingested daily via network are archived onto the jukebox following quality checks.

3. EOSDIS

The Hydrologic Cycle DAAC is one of nine DAACs established for NASA's Earth Observing System (EOS) Data and Information System (EOSDIS) Project. EOS and EOSDIS are part of NASA's contribution to the U.S. Global Change Research Program, an interagency effort of the U.S. Government to develop a predictive understanding of the global environment. In support of the EOSDIS mission, the Hydrologic Cycle DAAC serves as the primary NASA data center for passive and active microwave processing. The current EOSDIS, known as Version 0 has been operational since August 1994.

As the data holdings increase, additional computation power, archive space, improved user access techniques, and larger volume distribution capabilities will be required. In 1996 the first release of the next generation EOSDIS, under development by Hughes Applied Information Systems of Landover Maryland, will be delivered to support the Tropical Rainfall Measuring Mission (TRMM) scheduled for launch in 1997. Three additional releases of EOSDIS will occur from 1997 through 2002, each with additional capability to support the EOS AM and PM missions. The largest information management system in history will be in place by the turn of the century to provide archive, access and distribution of hundreds of terabytes of earth science data.

4. SURVEY OF HYDROLOGY DATA SETS

The Hydrologic Cycle DAAC currently maintains a collection of remotely sensed and in situ data sets relevant to hydrology research. The remotely sensed data holdings are derived from data collected by instruments aboard earth orbiting satellites like the DMSP, GOES, GMS and Meteosat geostationary satellites, and NOAA orbiters (TIROS and Nimbus). In-situ data are predominately measurements from surface and shipboard rain gauges and composite radar data from National Weather Service Radars. Several regional climatology data sets are also archived including hydro-meteorological data for the Continental United States, Amazon River Basin precipitation and numerous measurements from the Western Pacific. This section provides a survey of those data holdings.

4.1 Special Sensor Microwave/Imager (SSM/I)

The majority of the current data volume at the Hydrologic Cycle DAAC is occupied by data sets derived from measurements of the Earth by SSM/I instruments aboard the DMSP satellites. DMSP satellites are near-polar orbiting platforms that fly a sun-synchronous path about the earth. For such orbits the time at which the satellite crosses the equator in its South to North transit is relatively constant with respect to local time. The first DMSP satellite, designated F8, was launched June 19, 1987. Since then three additional satellites have been launched, designated F10, F11 and F12. These data are of particular interest to hydrology research because they can be used to derive geophysical parameters such as precipitation, water vapor, cloud water content, land classification, and land surface temperature.

The SSM/I instrument aboard these satellites is a seven-channel, four-frequency, passive microwave radiometer. The frequencies that are sensed are 19.3, 22.2, 37.0, and 85.5 GHz. Each of these are dual polarized except for the 22.2 GHz band which is a vertical polarization only. The Hydrologic Cycle DAAC has SSM/I data in several formats which are presented below.

4.1.1 SSM/I Wentz Antenna Temperatures

Remote Sensing Systems (RSS) of Santa Rosa California produces SSM/I Antenna Temperature products for commercial consumption (Wentz 92). The Hydrologic Cycle DAAC has acquired two of these data sets, from the F8 and F10 satellites respectively, which can be distributed at no cost to the research community. The F8 data set covers the time period from July 9, 1987 through December 31, 1991. The F10 temporal coverage is from December 8, 1990 through December 31, 1991. These data are available on magnetic media where one month of data occupies an 8mm tape cartridge. The total volume of these data sets is 53.3 and 7.4 GBytes respectively.

4.1.2 SSM/I Wentz Geophysical Products

Another SSM/I product suite produced by Remote Sensing Systems is a collection of antenna temperatures from three channels (19.3, 22.2, 37.0) and derived measurements of water vapor, cloud liquid water, and wind speed over oceans. Similar to the Antenna Temperatures the Hydrologic DAAC has acquired these data for the F8 and F10 satellites. The temporal coverage of these data is the same as for the antenna temperatures. The data volumes are 14.0 and 9.0 GBytes respectively.

4.1.3 The NOAA-NASA SSM/I Pathfinder Project

Another version of the SSM/I Antenna Temperature products for the period August 1, 1987 through December 31, 1988 for DMSP Satellite F8 also exists. This data set was produced as one of the seven data sets sponsored by NASA's Pathfinder program. The geophysical data is the same as that described in section 4.1.1 above, however this version has been thoroughly quality assessed and reformatted. Data that was out of bounds or otherwise inaccurate has been flagged. The versatile Hierarchical Data Format (HDF) was used to enhance transportability of this data set to a large variety of computer platforms. This data set occupies a volume of 38.5 GBytes.

In addition to the antenna temperature product just described, several geophysical products were also produced for the same time period. They are: 1) an atmospheric moisture product containing global cloud liquid/rain water, columnar water vapor and marine wind speed; 2) a precipitation rate product which depicts global precipitation rate estimates over land and ocean; and 3) a land surface product containing global classifications for various surface types. The volumes for these geophysical data are 7.0, 21.5, and 7.0 GBytes respectively.

4.1.4 SSM/I Level 1B Sensor Counts

Another source for SSM/I data available to the Hydrologic Cycle DAAC is the NOAA National Environmental Satellite Information Service (NESDIS). The format of this data is different than that from RSS and that of the NOAA-NASA Pathfinder program. Sensor counts from each of the seven SSM/I channels on DMSP satellites F8, F10 and F11 have been obtained from NOAA/NESDIS and are currently available from the Hydrologic Cycle DAAC. The low level, sensor count data set can be converted to either antenna temperatures or brightness temperatures by applying available computer programs. Hot and cold calibration values as well as quality control assessment flags are stored within the file.

The temporal coverage of these data sets is Jan. 4, 1992 through July 31, 1994 for F8; March 6, 1992 through present for F10; and March 17, 1992 through present for F11. The data volumes are approximately 75 GBytes for each.

SSM/I sensor count data sets are also available for the period and area of the TOGA COARE project. This intensive observation from November 1, 1992 through Feb. 28, 1993 was designed to investigate the structure of the coupled system of the warm pool of the western Pacific. Sensor counts from the F8, F10 and F11 DMSP satellites are available for

both the TOGA COARE Inner (10 degrees S to 10 degrees N by 140 degrees E to 180 degrees W) and outer (30 degrees S to 30 degrees N by 120 E to 160 degrees W) regions. The inner TOGA COARE data set volumes are 1GByte each. The F8 outer TOGA COARE volume is 5.5 GBytes while the F10 and F11 are 6.5 GBytes each.

4.1.5 SSM/I Temperature Data Records (TDRs)

Yet another format of SSM/I data are the TDRs. This data originates from the Fleet Numerical Meteorology and Oceanographic Center (FNMOC) and is obtained by the Hydrologic Cycle DAAC from NOAA/NESDIS. This data stream is ingested daily and is composed of orbit files that are combined to form daily granules. The format is different from any of the previously described SSM/I data but the content is still the same. The Hydrologic Cycle DAAC will be shifting to this data stream in the near future as a replacement to the NESDIS Level 1B sensor counts.

TDRs are available for the DMSP F10 and F11 satellites. The start date for the F10 platform is Oct. 5, 1994 and Nov. 16, 1994 for the F11. These data are ingested daily and will continue for the foreseeable future.

4.2 Microwave Sounding Unit (MSU) Global Temperature Anomalies

Microwave Sounding Units have been flying on NOAA's TIROS satellites continuously for over 15 years collecting measurements of thermal emissions of molecular oxygen from different altitudes in the earth's atmosphere. The four MSU frequencies near 60 GHz are sensitive to emissions from altitudes near the earth's surface all the way up to the lower stratosphere. Spencer and Christy have demonstrated that accurate estimates of global atmospheric temperatures could be derived from the MSU measurements. At the Hydrologic DAAC there are seven data sets produced by Spencer and Christy that contain atmospheric temperature anomalies. These data sets are arranged according to MSU channel, type of correction employed, and period of averaging.

4.2.1 Monthly Gridded Temperature Anomalies

Three of the data sets are global monthly averages of temperature anomalies presented on a 2.5 degree by 2.5 degree grid. All of these data sets utilize the Limb90 correction (Spencer and Christy 90). These data sets depict measurements from channels 2, 2R and 4 representing temperatures from the troposphere, lower troposphere, and stratosphere respectively. All three of these data sets cover the period from the present

back to January 1, 1979 and are ongoing. Current data holdings as of July 1994 are 10 MBytes for each of the monthly products.

4.2.2 Daily MSU Products

As with the Monthly Gridded Temperature Anomalies the daily MSU products are organized by MSU channel differences and type of correction applied. The first of these data sets contains zonal temperature anomalies of brightness temperatures in the lower stratosphere as measured by MSU channel 4 with Limb90 correction. The other four products use the Limb93 correction technique (Spencer and Christy 93). In addition Spencer has been able to utilize data from MSU channel 3 to remove stratospheric influences on MSU channel 2 and to combine MSU channels 3 and 4 to calculate the temperature in the upper troposphere in the tropics. All of these data sets have a temporal coverage from January 1, 1979 through December 31, 1993. The volume of each data set is 240 MBytes.

The final data set in this class is a daily data set of Oceanic Precipitation estimates based on the physical phenomena of increased warming of MSU channel 1 (Spencer and Christy 93b). The increased warming is attributable to emission by liquid water in the lower troposphere. The precipitation estimate has been calibrated into mm/day rainfall using eight years of rain gauge data from tropical island locations.

4.2.3 NOAA-NASA TOVS Pathfinder (MSU)

The second Hydrologic Cycle DAAC data set that is also a Pathfinder data set is a collection of seven TIROS Operational Vertical Sounder (TOVS) level 3 geophysical parameters organized into daily, pentad and monthly files. The data in this data set is the same geophysical information as that described in sections 4.2.2 but organized differently and packaged as HDF scientific data sets (SDSs). Specifically, each file contains lower troposphere deep layer mean temperature estimates, lower stratosphere deep-layer mean temperature estimates, oceanic precipitation estimates, two grid point standard deviations for channels 2/3 and 4, and grid point sample count parameters also for channels 2/3 and 4. The data sets are further broken into ascending (AM) and descending (PM) time periods for each of the three temporal ranges of the data sets.

The temporal coverage for each of these data sets is from March 1, 1987 through November 30, 1988 the benchmark period defined by the Pathfinder Project. The volumes of these data sets are 30 MBytes for the monthly, 180 MBytes for the pentad and 900 MBytes for the daily files.

4.3 Other Remote Sensed Data Sets

4.3.1 Scanning Multichannel Microwave Radiometer (SMMR)

The SMMR Antenna Temperatures data set consists of antenna temperatures from passive microwave radiometers aboard NOAA's Nimbus-7 satellite. The instrument has ten channels - dual polarizations at 6.6, 10.69, 18.0, 21.0 and 37.0 GHz. The two 37.0 GHz radiometers operated continuously for each polarization while the other four alternated polarizations on successive scans. The data are archived in daily files. Each file is 35 MBytes in size. Data are available from Oct. 25, 1978 through Nov. 20, 1987.

Two other atmospheric products derived from SMMR data are available from the Hydrologic Cycle DAAC. Dr. Prabhakara Cuddapah of GSFC produced an Atmospheric Liquid Water content and Atmospheric Water Vapor content product. The Atmospheric Liquid Water product contains monthly mean liquid water values on a 3 by 5 degree grid over an area from 48 degrees S to 48 degrees N and 180 degrees W to 180 degrees E. The temporal coverage of this data set is from Feb. 1, 1979 to May 31, 1984.

The Atmospheric Water Vapor product is also a monthly mean on the same size grid but covering an area 75 degrees S to 75 degrees N and from 180 degrees W to 180 degrees E. The temporal coverage for this data set is from Oct. 1 1979 to Sept. 30, 1993.

4.3.2 Janowiak and Arkin GPCP Satellite Derived Monthly Rainfall

This data set consists of mean monthly rainfall totals computed from IR estimates from GOES, GMS and Meteosat geostationary satellites (Janowiak and Arkin). The data is gridded on a 2.5 by 2.5 degree cell. The spatial coverage is from 40 degrees N to 40 degrees S about the entire earth. The temporal coverage is from 1986 to the present. The current volume of this data set is 3.5 MBytes. It may be directly accessed from the Hydrologic Cycle DAAC via anonymous ftp.

4.4 Surface Data Sets

4.4.1 Jaeger Monthly Mean Global Precipitation

The Jaeger observations consist of mean monthly precipitation totals over the continents and oceans for an extended period (Jaeger). The continental observations were obtained from surface rain gauge measurements taken from 1931 to 1960. These data were gridded by employing manual estimates of grid points from up-to-date climatic

atlases containing annual and monthly rainfall values, supplemented by other data sets.

The ocean precipitation values were determined by using Moller's method for estimating rainfall frequencies. Monthly percentage frequencies were extracted from the mapped isolines of the US Marine Climatic Atlas and interpolated to the grid points. After re-expressing the monthly frequencies as annual percentages, the values were scaled to rainfall depth units using Geiger's precipitation map to yield monthly precipitation means.

These two techniques were combined to produce monthly, seasonal, and annual variations of precipitation over the entire globe. This data set is available via anonymous ftp at a volume of only 126 KBytes.

4.4.2 Legates Surface and Ship Observation Precipitation

Another rain gauge data set available from the Hydrologic Cycle DAAC is the Legates Surface and Ship Observations (Legates). This is a global data set that contains mean monthly precipitation values. Data were obtained from a variety of sources including traditional land-based rain gauge measurements, oceanic precipitation from coastal and island observations, and shipboard rain gauge observations. These data were screened for errors, and redundant station readings yielding a data set containing 24,635 independent terrestrial station records and 2223 oceanic grid point estimates.

Since errors from rain gauge readings can result from a variety of factors a procedure was developed to make corrections. The effects of wind, wetting losses, and evaporation can yield errors of 8, 2, and 1 percent respectively. The procedure effectively corrects for these errors.

The data set has a long temporal coverage from January 1920 through December 1980. It has been used to validate general circulation models of the present-day precipitation climate for ground-based comparison with satellite-derived precipitation estimates, and as a basis for global water balance studies. The data set is available via anonymous ftp.

4.4.3 Amazon River Basin Precipitation

The monthly precipitation data in this data set were derived from a rain gauge network operated by the Divisao Nacional de Aguas e Energia Electrica (DNAEE). As the name implies this is a regional data set which covers the critical area of Brazil's Amazon River and tributaries. The precipitation measurements are provided as a monthly total on a 0.2

degree grid. The grid values are determined through a linear interpolation of all stations within one degree with a minimum of four stations. The values are in mm/month. Monthly data sets from Peru and Bolivia were combined with daily readings from Brazil to extend the data set range. The spatial coverage is an area 20.2 degrees S to 5.6 degrees N by 79.8 degrees W to 45.6 degrees W.

These data were utilized by the EOS Amazon Project (EOSAP). The EOSAP includes both empirical and modeling studies of rainfall and runoff from sample hill slopes to the entire Amazon basin.

The data set covers a 21 year period from January 1972 through December 1992. It is available via anonymous ftp from the Hydrologic Cycle DAAC. The data volume is 3.5 MBytes. There are 21 files where each file contains 12 images. Each image is in a 129 by 171 element array.

4.4.4 Wallis, Lettenmaier and Wood Hydroclimatology Data

A daily hydro-meteorological data set for the continental United States was constructed for use in climate studies (Wallis, Lettenmaier and Wood). These data were taken from USGS daily stream flow data and NOAA daily climatological for precipitation, maximum and minimum temperature.

The data set uses a set of 1009 USGS stream flow stations, and 1036 NOAA climatological stations, for which long term (1948-1988) observations have been assembled into a consistent data base with missing observations estimated using a simple closest station prorating rule. The climatological stations are a subset of the Historical Climatology Network.

The data are retrievable by station list, state, latitude-longitude range, and hydrologic unit code. The data are available on CD-ROM from the User Services Office of the Hydrologic Cycle DAAC.

4.5 Aircraft Based Observations

4.5.1 Advanced Microwave Precipitation Radiometer (AMPR)

AMPR remotely senses passive microwave signatures of geophysical parameters from an airborne platform (Spencer, Hood, et al). The instrument is a low noise system which can provide multifrequency microwave imagery with high spatial and temporal resolution. AMPR data are collected at combination of frequencies (10.7, 19.35, 37.1 and 85.5 GHz) unique to current NASA aircraft instrumentation. These frequencies are well suited to the study of rain cloud systems, but are also useful to studies of various ocean and land surface processes.

AMPR was deployed in the western Pacific ocean region for TOGA/COARE during January and February of 1993. The TOGA/COARE data set and other AMPR data are available via anonymous ftp.

5. FUTURE DATA HOLDINGS

The Hydrologic Cycle DAAC continually evaluates data sets for inclusion in its archive. Just recently the Hydrologic DAAC Science Advisory Board recommended the acquisition of data from the Midwest Floods of 1993. This data set should be available for order by Spring 1995. The Hydrologic Cycle DAAC is participating in the Global Energy and Water Cycle Experiment Continental-scale International Project (GEWEX/GCIP). In this the DAAC serves as the Satellite Data Module, coordinating access to satellite derived products located within EOSDIS and other GCIP data centers.

The largest data acquisition by far will begin in 1997 with the launch of the Tropical Rainfall Measuring Mission (TRMM). With that mission the Hydrologic Cycle DAAC will begin archiving data from three TRMM instruments as well as ground validation data. The TRMM Microwave Imager (TMI), Precipitation Radar (PR), Lightning Imaging Sensor (LIS) and precipitation data from ground radars will provide a flow of over 10GBytes of data per day into the DAAC archive systems. This data should be of great asset to the Hydrology community because of the nature of the TRMM objectives. Data will be gathered from 35 degrees N to 35 degrees S continuously and made available to the scientific community within a few hours.

6. HOW TO ORDER

The data holdings of the Hydrologic Cycle DAAC are accessible in several ways. A comprehensive description of the DAAC is provided by the WWW server. You can use anonymous ftp or access the on-line Information Management System via telnet. The User Services Office staff will also be happy to answer any questions you may have and will assist you in locating hydrologic data sets, even if they are not archived at the Hydrologic Cycle DAAC. All of the data are currently available at no cost.

WORLD WIDE WEB:
Anonymous FTP:
TELNET:
Telephone, Fax, E-mail & Mail:

<http://wwwdaac.msfc.nasa.gov>
<ftp://microwave.msfc.nasa.gov>
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